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SUNFLOWER POWER CONVERSION SYSTEM

284

QUARTERLY REPORT

SEPTEMBER – NOVEMBER 1960

TAPCO GROUP

Thompson Ramo Wooldridge Inc.

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PRESENTED BY:

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TABLE OF CONTENTS

LIST OF FIGURES FOR QUARTERLY

I. PROJECT OBJECTIVES

The Sunflower I solar power system objective is to develop a highly reliable power conversion system which is capable of providing a continuous electrical power output from .3 to 3 KW in circular earth orbits from 300 to 20,000 nautical miles. The system shall collect the sun's energy in a solar collector and focus this energy in a boiler/ heat storage receiver cavity. Mercury shall be heated in the boiler and used in turn to drive the turbine. A directly coupled alternator shall produce the desired output power and the rotational speed of the unit shall be monitored by a parasitic load frequency sensing control. The system shall be capable of operation in all earth orbits between 300 and 20,000 nautical miles and withstanding orbital transfers which require ± 1 g force in any direction. The system shall be delivered in three years and shall have demonstrated at least 90 days endurance capability. A one year endurance capability shall be demonstrated in four years.

II. PROJECT OBJECTIVES FOR THE REPORTING PERIOD OF SEPTEMBER 1 TO DECEMBER 1, 1960

Finalization of breadboard designs and the initiation of component testing were the overall program objectives for this reporting period. Lithium hydride corrosion capsules and breadboard condenser and boiler/heat storage units have been fabricated and tested. The orbital start tank has been built.

Design approach for the rotating package for the system has also been finalized. The Sunflower program does not presently budget funds for development activity in basic design of the rotating package and, therefore, motivates the use of SNAP II hardware where applicable. The decision to use SNAP II technology and development experience was the major factor dictating the use of the separable shaft and wheel design.

The Sunflower overall project has been rebudgeted to include more accurate manpower allocations, actual costs incurred through September, and addition of the Lithium Hydride Thermal Properties Supplement.

Construction of the new facility has been completed except for the portion of the floor area over which the shaker will be installed and transported.

The Burroughs 205 Computer Program for determining the boiler performance map has been modified to reflect recent correlation data for friction factors and two-phase pressure drop. In addition, steady-state component performance data has been completely programmed for analogue simulation except for incorporation of steady-state characteristics of the boiler.

The system and component specification has been modified to reflect a more conservative prediction of turbine efficiency and mercury pump power requirements, but component and system weight objectives remain unaltered.

Test rig design and procurement of required equipment continued throughout the quarter but was delayed somewhat by changes made mandatory through evaluation of the lithium hydride test safety requirements. All-out effort is being expended to maintain the completion schedules so that preprototype hardware testing can be accomplished on schedule.

During this quarter the Lithium Hydride Thermal Properties Supplement was negotiated and the proposed Sunflower Solar Test Supplement modified. Also, preliminary talks with NASA were directed toward proposing supplemental ballistic experiments to enhance overall system reliability and performance.

III. PROJECT PROGRESS DURING REPORTING PERIOD

PROJECT MANAGEMENT AND SYSTEM ANALYSIS

NASA and TRW personnel completed final negotiations of the Lithium Hydride Thermal Properties Supplement in mid-September. Objectives are the actual measurement and determination of the physical properties of lithium hydride, including measurement of thermal conductivity, heat capacity, and heat of fusion of liquid and solid commercial-grade lithium hydride under the following conditions: (1) original purity, (2) after addition of LiO, (3) after addition of Li metal, and (4) after addition of various materials which simulate corrosive attack of containment vessel walls.

At the request of NASA, the proposed Sunflower Solar Supplement was reviewed. Certain areas of testing were eliminated to reduce the overall program cost. Proposed revisions include the following:

1. Deletion of solar collector testing on the 40-foot collector,
2. Reduction of the 40-foot backup collector to a 32-foot backup structure,
3. Elimination of collector radiometer testing on the prototype collector,
4. Reduction of overall program length.

Discussions were held with NASA personnel regarding supplemental support of the development program by performance of ballistic test shots of components and complete systems. It appears feasible and attractive to use this means to obtain a thermal evaluation of the collector, collector efficiency, kinematics of collector deployment, aerodynamic loading of the collector, heat rejection from radiation, and temperature measurements of the radiator surface. Later tests are contemplated to provide entire system checkout.

A preliminary evaluation indicates that a multiplicity of trial and error solutions are required to achieve a final off-design performance evaluation. An effort was therefore initiated to program steady-state component performance data for analogue simulation. This has been completed with the exception of incorporating the steady-state component characteristics of the boiler.

The Burroughs 205 computer program for determining the boiler performance map essential in the evaluation of system design and off-design performance was modified to reflect recent modifications in correlation data for friction factors and two-phase pressure drop. Mercury pump performance data from recent tests will be used to correlate flow and boiling pressure. Results of this effort will be available in December.

Changes to define in more detail the position of the condenser-subcooler interface in terms of variations in condenser pressure are being programmed.

As a result of continual evaluation of component characteristics, the system specification has been modified to adjust predictions of turbine efficiency and mercury pump power requirement. Figure 1 shows the revised Sunflower mercury Rankine cycle based upon a turbine efficiency of 51 percent and added pump power requirements of 60 watts. The bases for change of turbine efficiency are discussed in detail in the turbine section of this report. The increase in mercury pump power is a consequence of a higher cycle flow requirement as well as changes in bearing flow requirements. Component specifications have been modified to reflect these changes in performance. Component and thus system weight specifications remain unaltered.

TEST RIG DESIGN AND FABRICATION

The new development laboratory at the Tapco Plant, shown in Figures 2 and 3, is nearing completion. The only task remaining is completion of the pits and trenches required for the vibration equipment, affected floor area, and completion of main access door.

A detailed investigation of the safety requirements of working with lithium hydride at elevated temperatures (1500 to 1600°F) was conducted. To be safe, the test cell design and test procedures must be compatible with the possibility of molten lithium hydride container rupture. To cope with this two solutions were proposed:

1. Enclose the boiler/heat storage unit in an argon-inerted dry box capable of containing the LiH + Heat reaction products.

2. Inert the entire test cell with argon.

A complete economic evaluation revealed that the two approaches are essentially equal in cost. Since the inerted cell significantly eases test operations, material handling and system design limitations, this alternative was chosen. Figures 4 and 5 are layouts of the test cells. Procurement specifications on these booths have been released for quotation.

All of the long-lead items for the auxiliary mercury booth have been purchased. Layouts of electrical, plumbing, and instrumentation consoles are nearing completion, construction of the auxiliary control consoles has been initiated, and specifications have been written for air conditioning and ventilating systems for the test cells.

POWER CONVERSION SYSTEM

The power conversion system layout is continually being modified to meet requirements of the system components and instrumentation as more detailed data is obtained. The CSU package has been placed farther from the focal point of the collector as a result of a layout study to evaluate the shading effects of components on overall system performance. In addition, the condenser has been moved nearer to the rotating package to provide a more compact packaging arrangement. A change in the condenser design has been effected in the area of the headers. Stress analysis indicates that the condenser tubes are best supported in a manner that will allow them to be in tension during acceleration

SUNFLOWER I — MERCURY RANKINE CYCLE

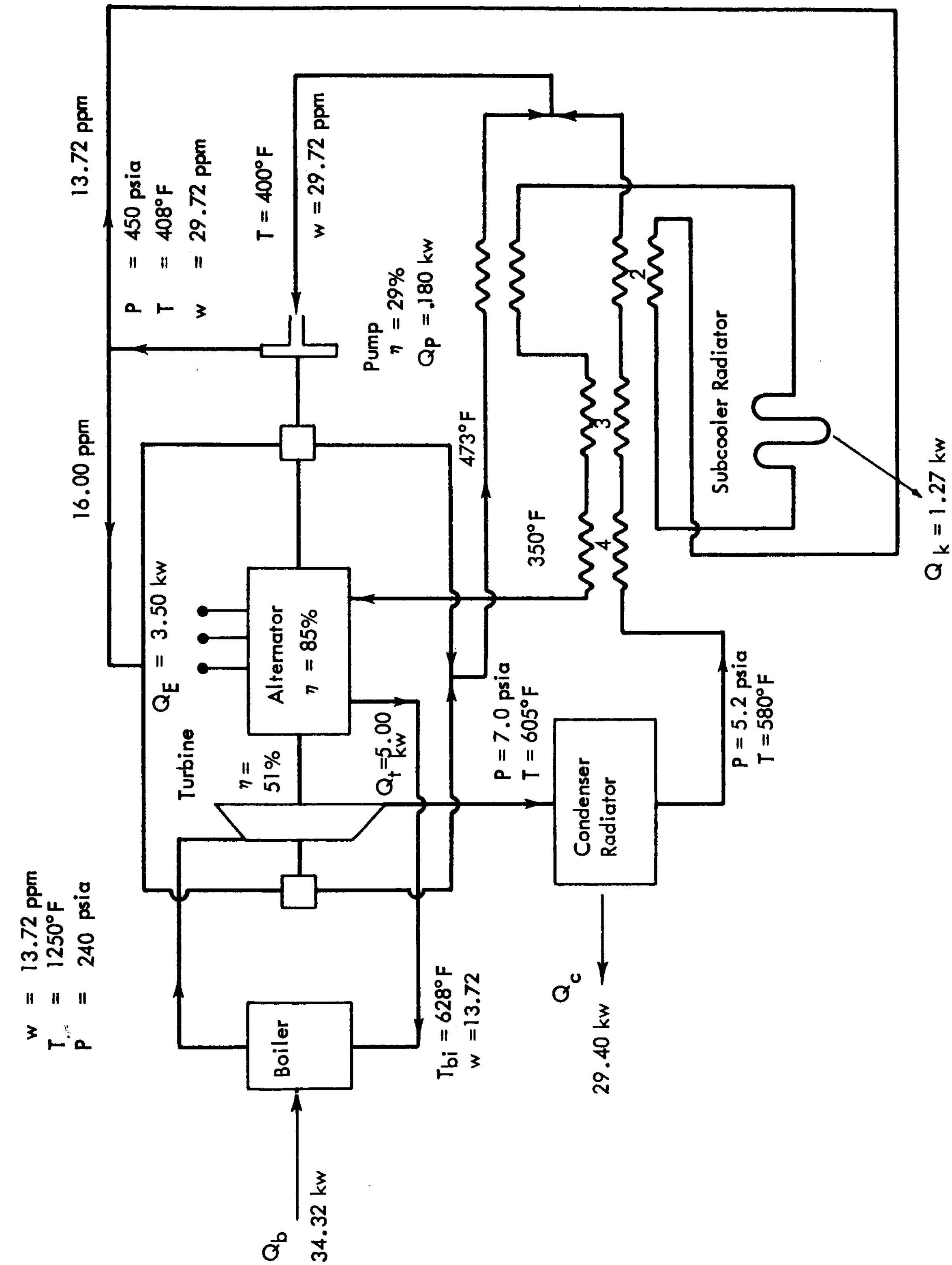
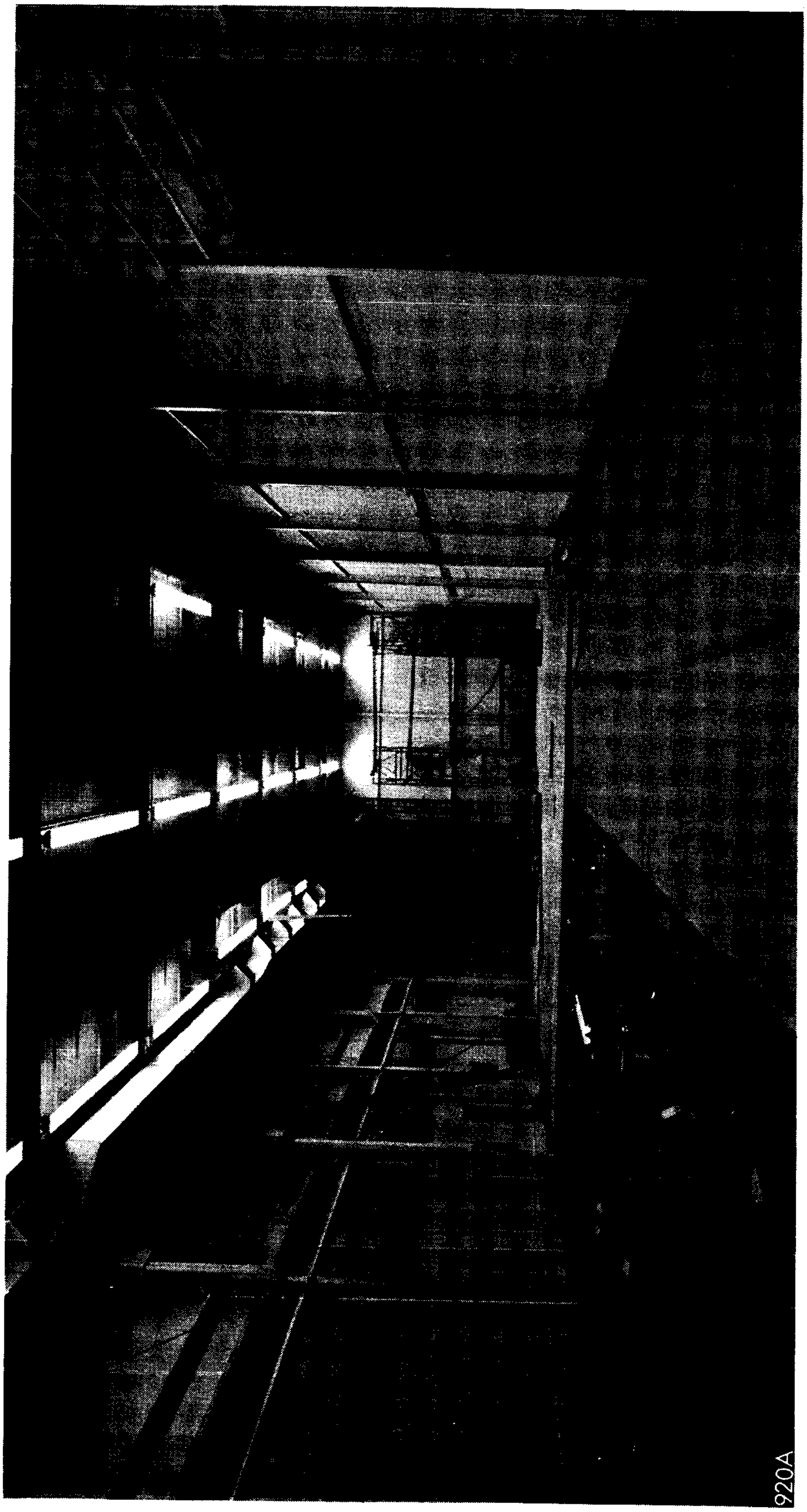


FIGURE 1

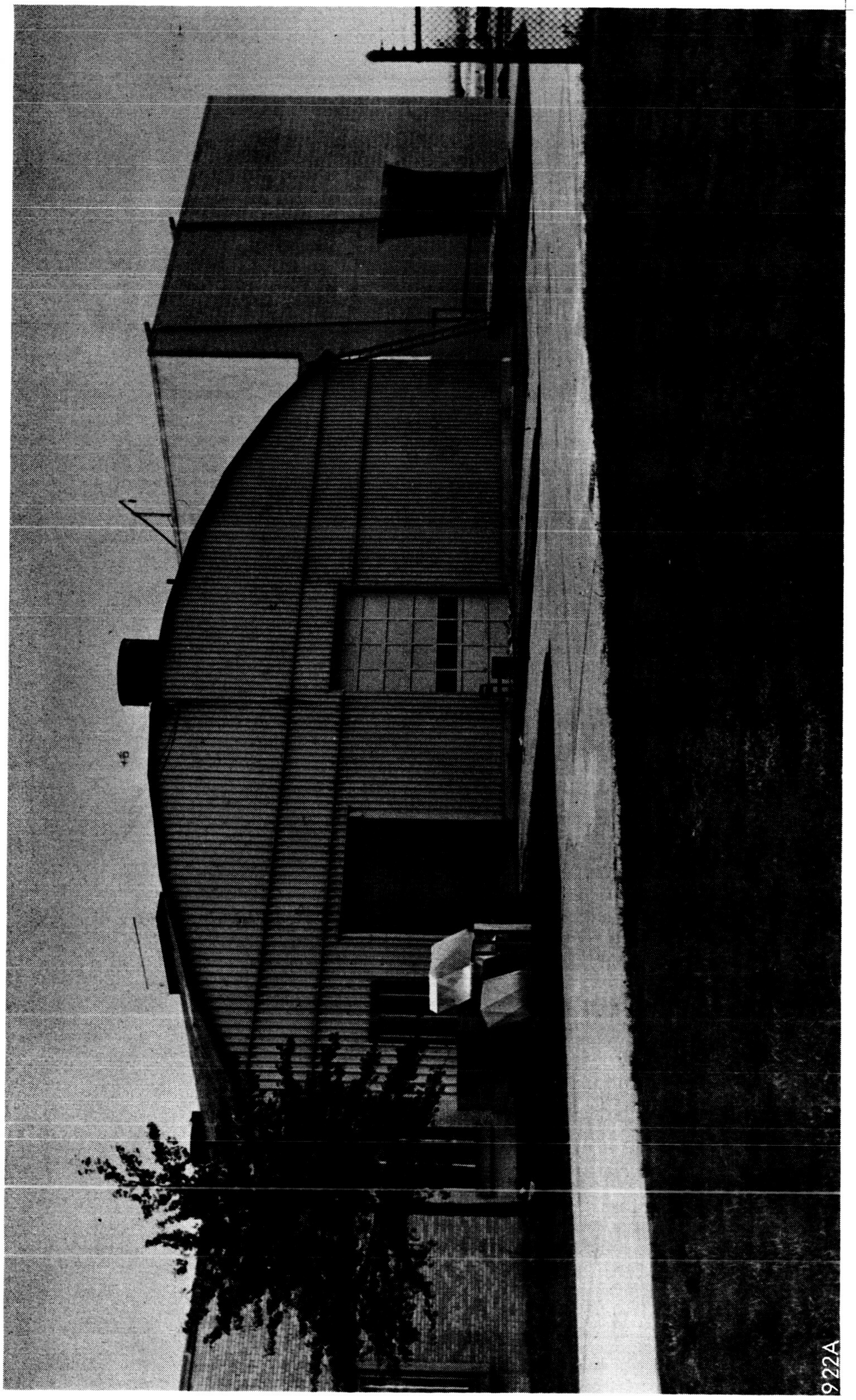


SUNFLOWER DEVELOPMENT LABORATORY, INTERIOR VIEW OF BLDG 41

FIGURE 2

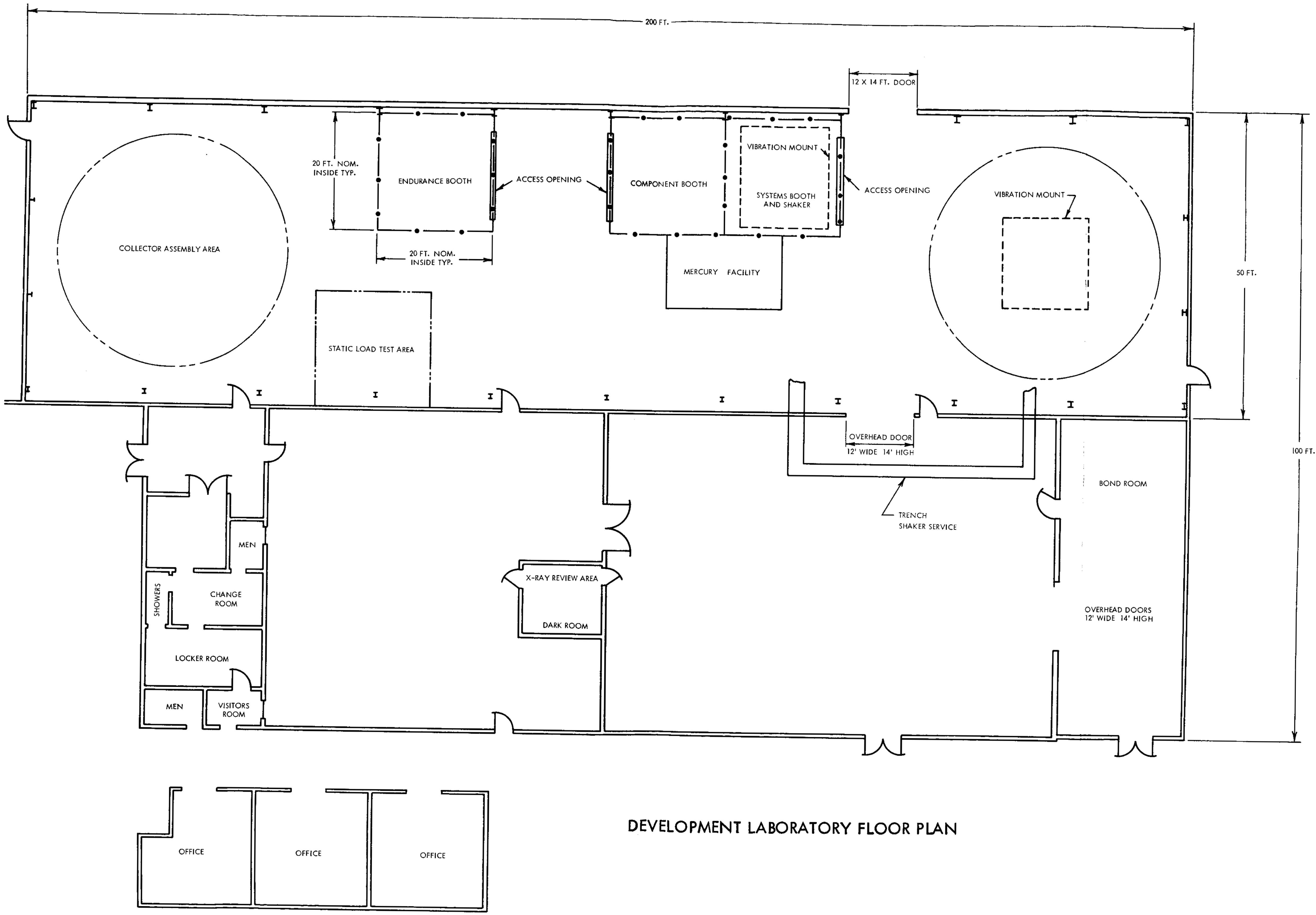
BLDG. 41

BLDG. 24



SUNFLOWER DEVELOPMENT LABORATORY, EXTERIOR VIEW

FIGURE 3



DEVELOPMENT LABORATORY FLOOR PLAN

FIGURE 4

ISOMATIC VIEW - ~~EN~~ DEVELOPMENT AND ACCEPTANCE TEST CELLS

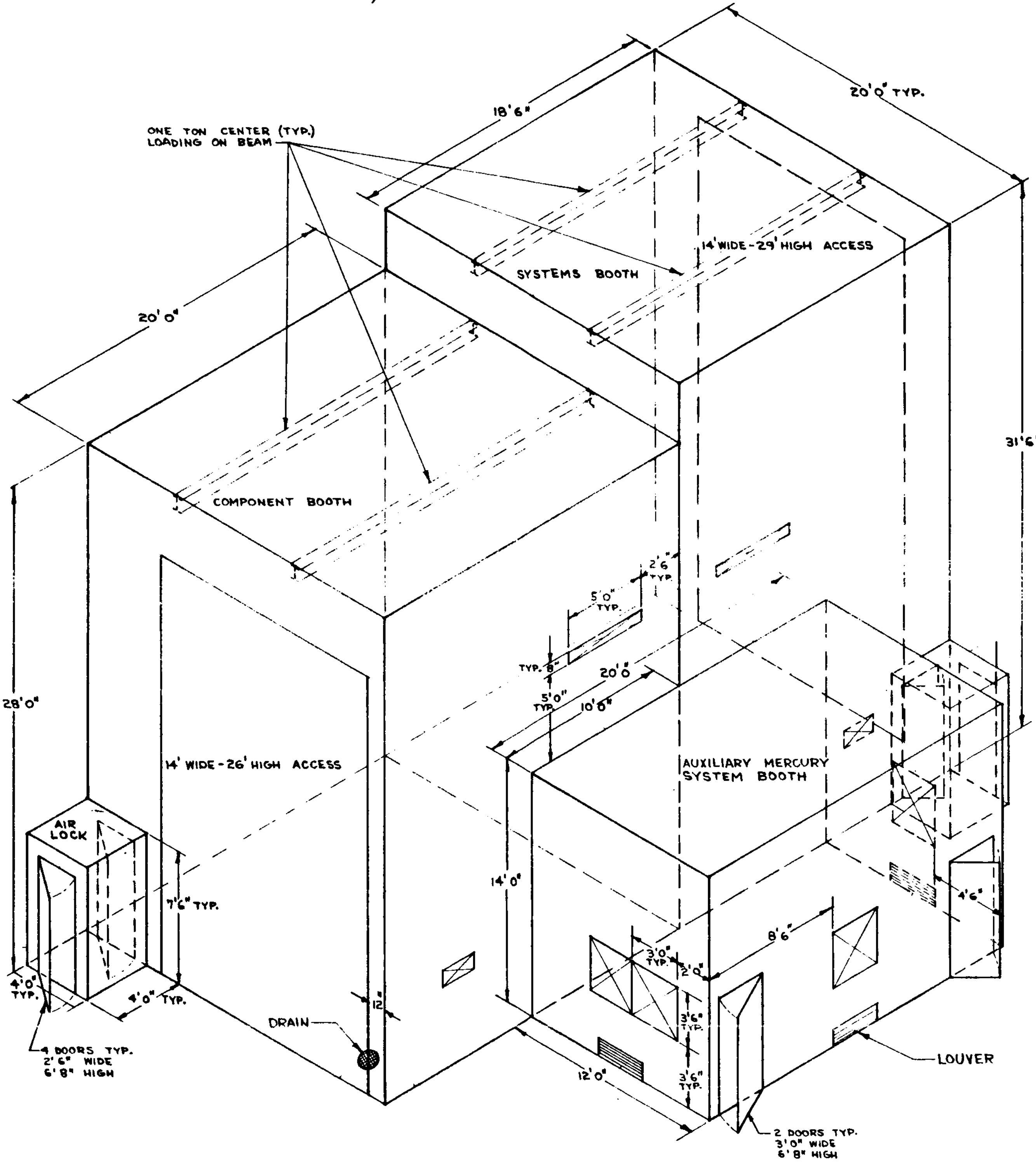


FIGURE 5

loading. The upper header has therefore been redesigned to withstand the resultant loadings imposed by acceleration of the condenser tubes and fins.

Figure 6 is a schematic drawing of the system instrumentation and plumbing. The current PCS layout is shown in Figure 7.

BOILER/HEAT STORAGE

Boiler/heat storage design activity has been primarily directed toward thermal optimizations and analysis of boiler tube weight, shell geometry and weight, fin configuration and weight, and pressure drop. Analyses indicate minimum boiler weight will be obtained by employing a single tube for the mercury flow and fins made of materials which possess high thermal conductivity and relatively low density. These considerations favor beryllium and graphite for the fins.

A breadboard program was initiated to test compatibility of these materials with lithium hydride. Three small test modules were manufactured of Type 316 stainless steel with no fins, beryllium fins and graphite fins.

The modules were completed and taken to Lithium Corporation of America for LiH loading. The first module to be filled with lithium hydride was the plain module with no fins. The filling was undertaken with painstaking care to keep the test module and hydriding equipment as free from contamination as possible, since it is believed that oxygen and nitrogen contribute substantially to corrosive attack. The process employed consisted of loading with molten lithium and hydriding in the module. Handling was accomplished under argon and hydrogen cover to the maximum extent possible.

The plain module with no fins was successfully filled and returned for testing in the breadboard test rig shown in Figures 8 and 9. The first test was primarily intended to gain experience with lithium-hydride handling techniques, obtain test rig shake down, and investigate the heat transfer through the LiH in both the solid and liquid states. Data on the compatibility of lithium hydride with the container materials was also sought.

On the second heat up cycle the module experienced an unexpected pressure relief in which liquid lithium hydride filled up a pressure gage line for about eight feet. The tape mounting a thermocouple to this gage line was ignited by the hot lithium hydride in the line, causing a small fire. Additional pressure build-up in the module was vented. The module was allowed to cool and the argon-inerted dry box opened. Lithium hydride spillage was evident. Leakage had occurred in the vicinity of a fitting on the fill tube of the module. The module was repaired by welding this fitting and has been returned to test.

A materials compatibility problem was experienced during attempts to fill the module with the graphite fins, confirming initial doubts about the compatibility of graphite and lithium hydride. A chemical reaction which produced methane, released hydrogen, and probably formed some lithium carbide compound resulted in disintegration of the fins.

SCHEMATIC OF PCS INSTRUMENTATION AND PLUMBING

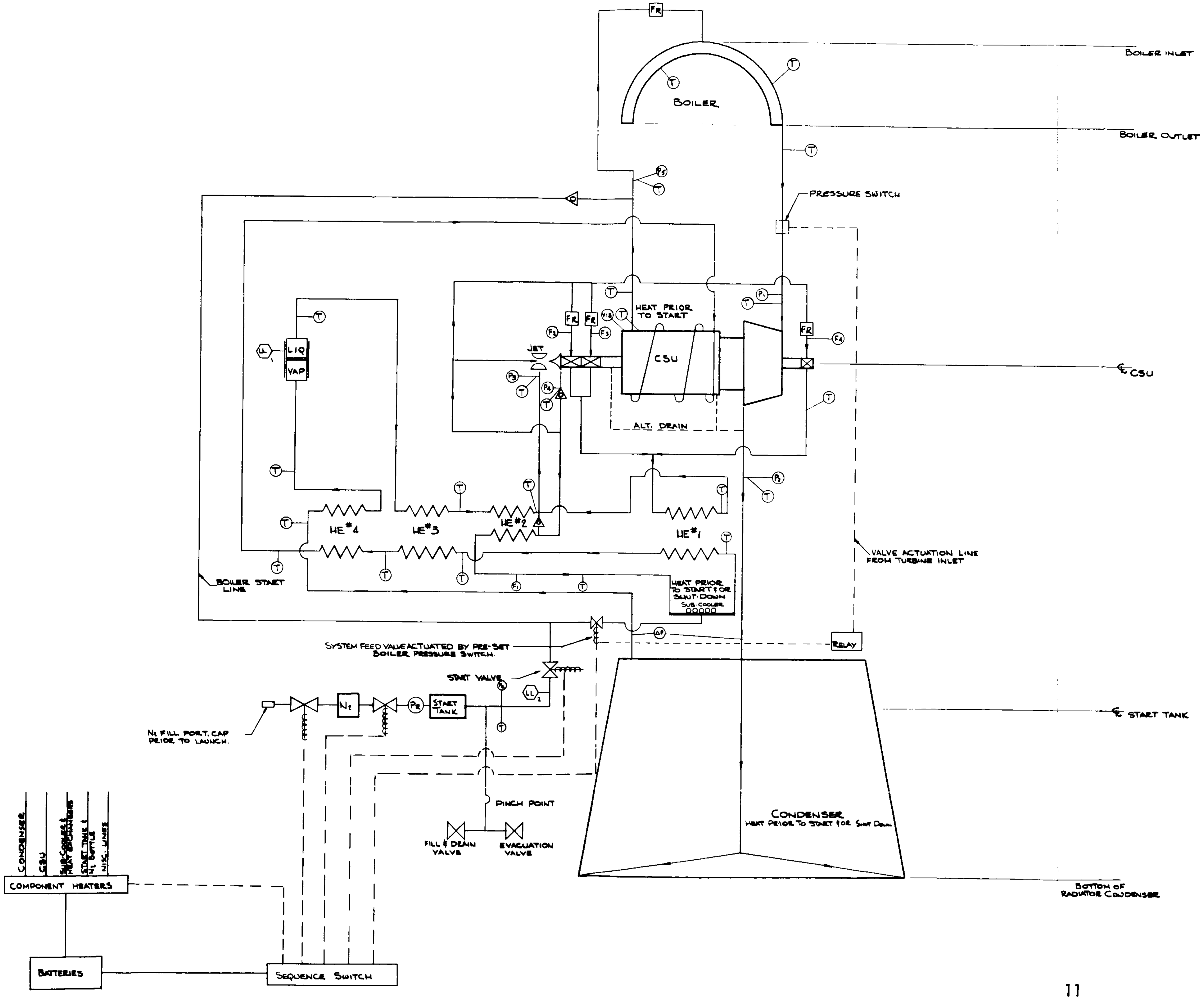
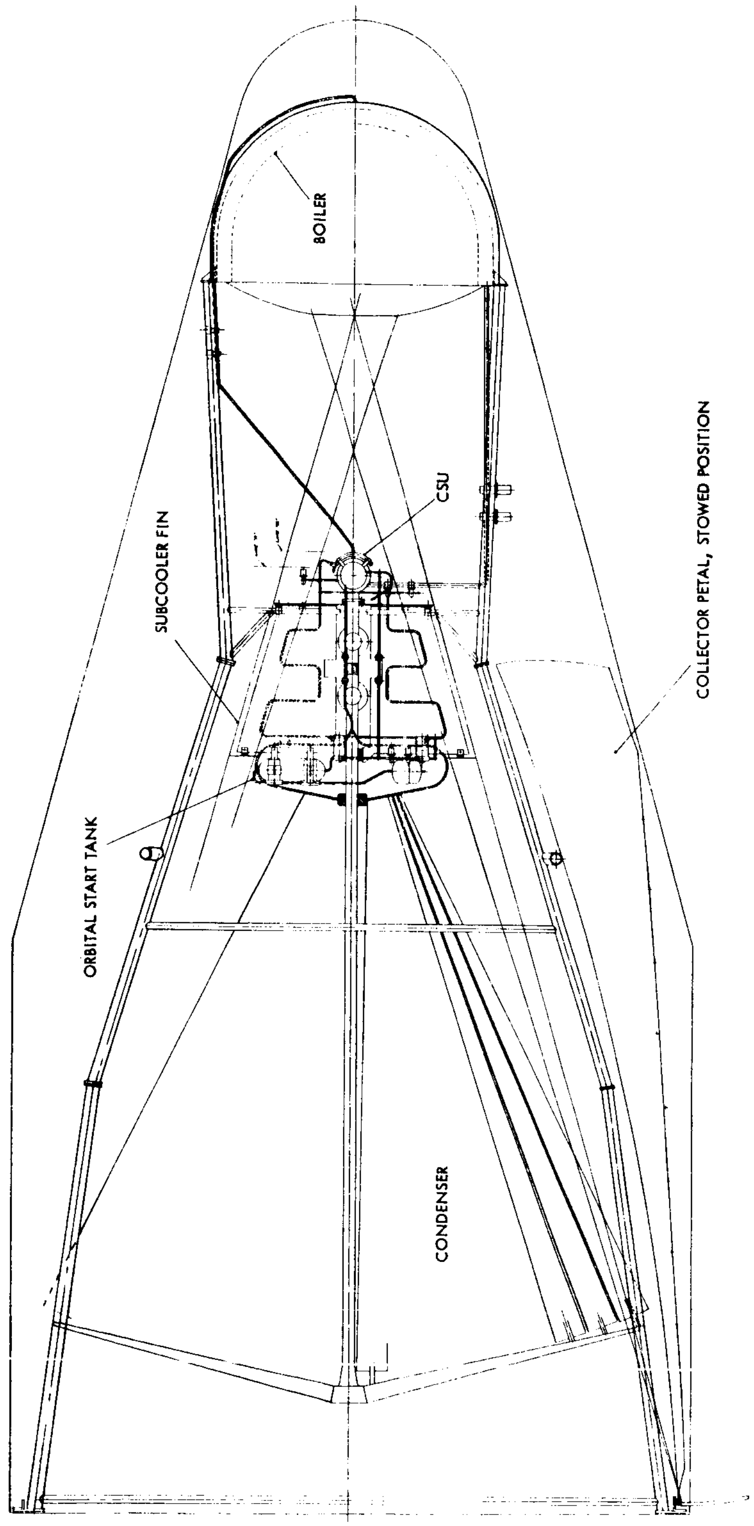
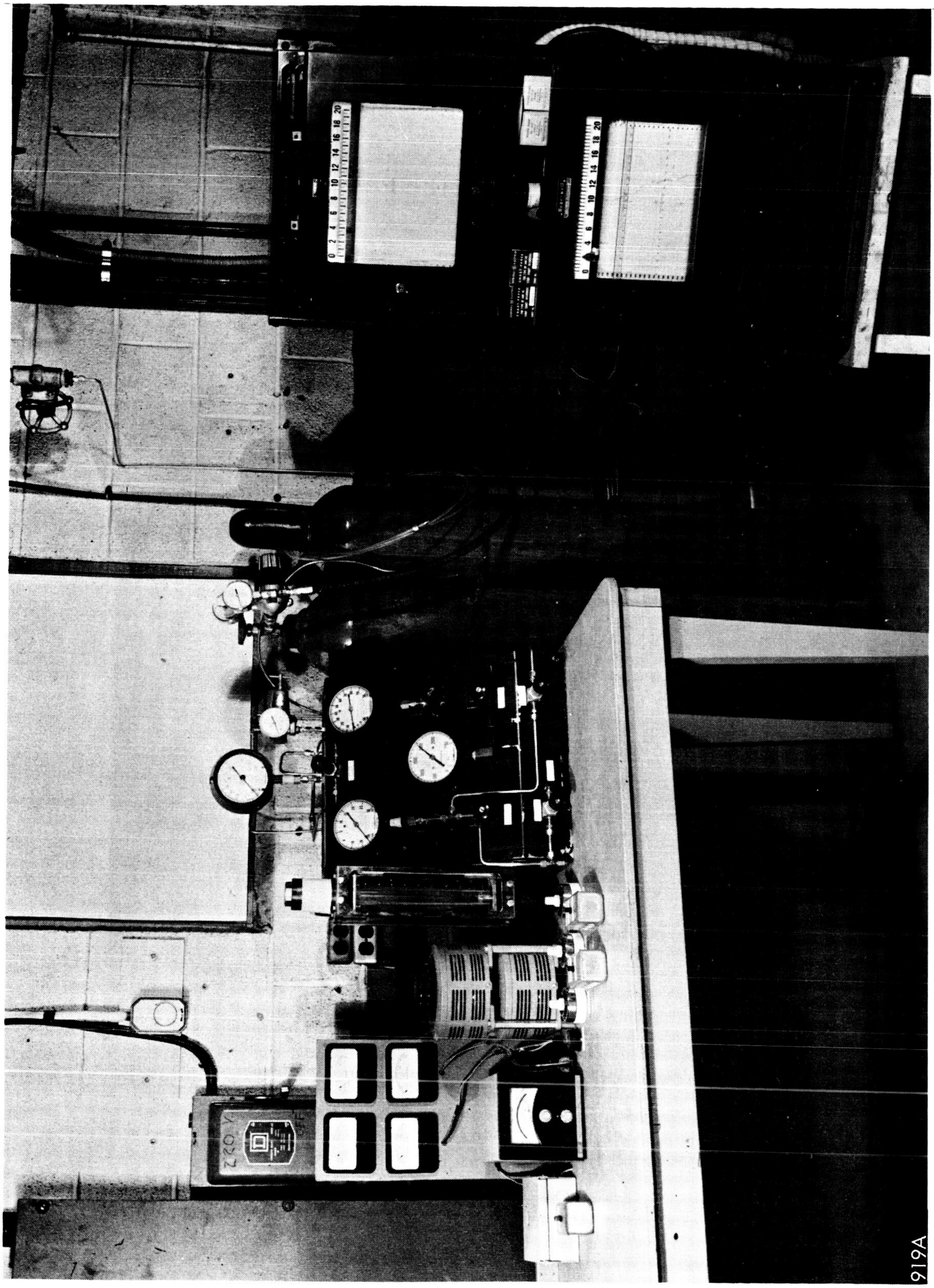


FIGURE 6



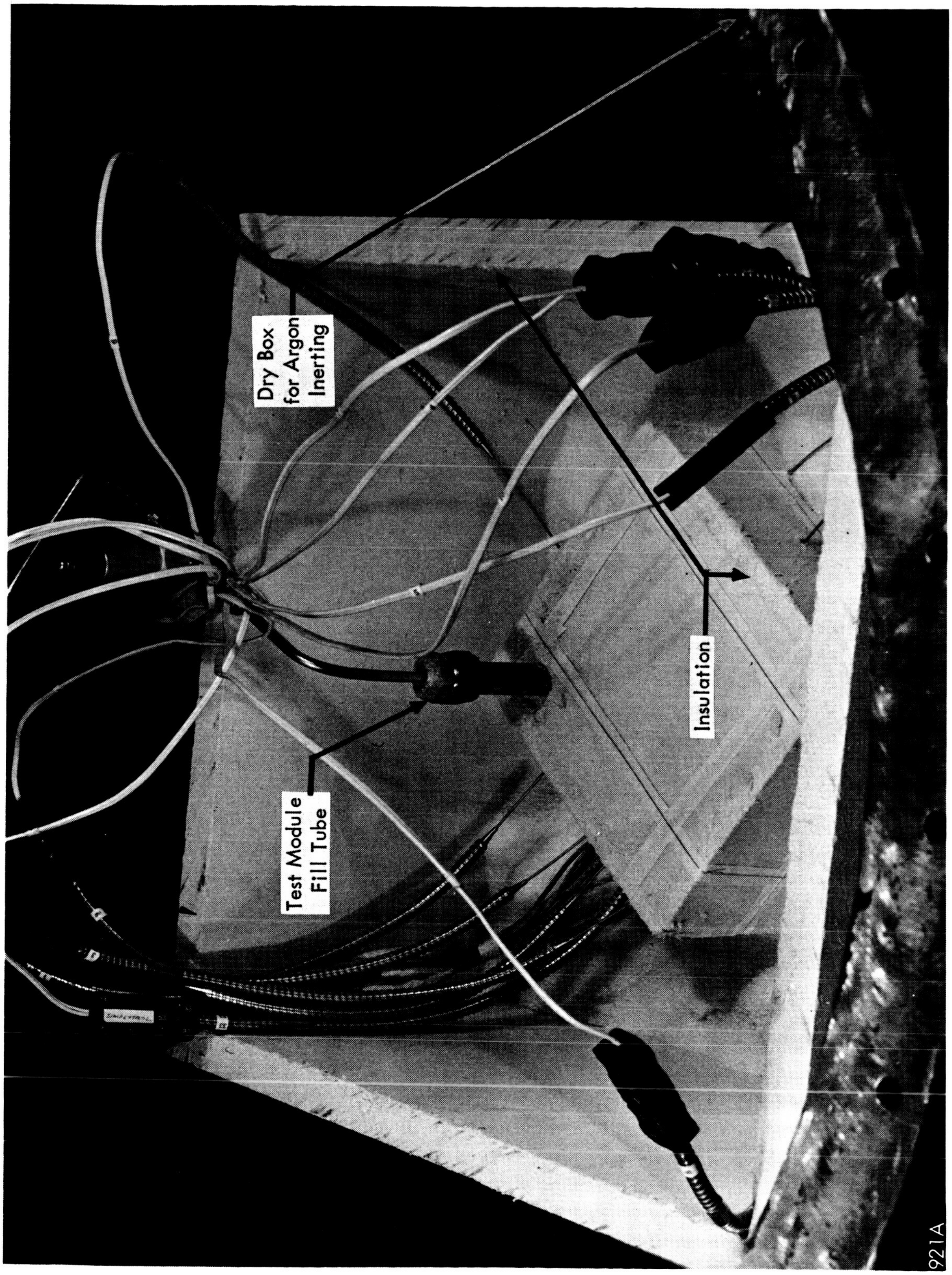
POWER CONVERSION SYSTEM LAYOUT

FIGURE 7



BOILER/HEAT STORAGE BREADBOARD TEST RIG INSTRUMENTATION AND CONTROL CONSOLES

FIGURE 8



BOILER/HEAT STORAGE BREADBOARD TEST RIG

FIGURE 9

Breadboard testing is continuing to identify a material with high thermal properties and low density which is compatible with lithium hydride. Test modules have been fabricated with molybdenum and with electrolytic iron fins. The units have been prepared for loading and will be filled with lithium hydride and placed in test in early December.

Investigations into material compatibility and strength at elevated temperatures have suggested molybdenum as the boiler material. Mercury corrosion testing on the SNAP II program also suggested molybdenum as a corrosion resistant material. The advantage of using molybdenum in boiler fabrication is evident when its ratio of high-temperature strength and density is compared to that of stainless steel:

10,000-Hr Stress-to-Rupture/Density Ratio		1500°F	1600°F
σ/ρ	moly	81,300 in.	27,600 in.
σ/ρ	316 SS	14,850 in.	4,900 in.

This ratio indicates the relative weight savings available in shell construction; however, the entire savings may not be achievable because practical fabrication considerations may govern, such as the wall thickness required to spin or form the shells as well as to provide the required protection against meteroids for the boiler/heat storage unit.

The disadvantages of molybdenum are susceptibility to oxidation at elevated temperatures, relative difficulty of forming and welding, and high cost. Oxidation at elevated temperature may be eliminated by use of coatings, remembering that system operation in space should not create this problem but that protection must be afforded the system during ground checkout, solar test activities, and system testing. The planned use of argon-inerted test cells for system test should reduce the oxidation problem during system tests. Drawings of the proposed preprototype boiler are shown in Figures 10 and 11.

SOLAR COLLECTOR

In preliminary ΔT testing of the collector, honeycomb samples were illuminated with radiant energy from a "guarded hot plate" heat source at pressures of less than 10^{-3} mm Hg. The test rig setup is shown in Figure 12. Tests are run with both room ambient and 77°K background temperatures.

While further testing is required on samples of different configuration details, the results to date are of interest. By performing the tests at various temperatures and heat fluxes and by comparing the results of configurations tested to date, insight has been gained in the relative contributions of conductive and radiative heat transfer coefficients. These have been analytically applied to investigate the transient temperature levels and face ΔT's as influenced by the low altitude sun-shade operation. Typical results are shown on Figure 13. An important indication is that ΔT is, as predicted earlier, much more stable than ambient temperature level, thus thermal distortions should be relatively constant with orbital periods. It remains advantageous to reduce face to face ΔT's. Since it appears that the major transfer mode is conduction, current investigations are

PREPROTOTYPE BOILER/HEAT STORAGE UNIT - SIDE VIEW

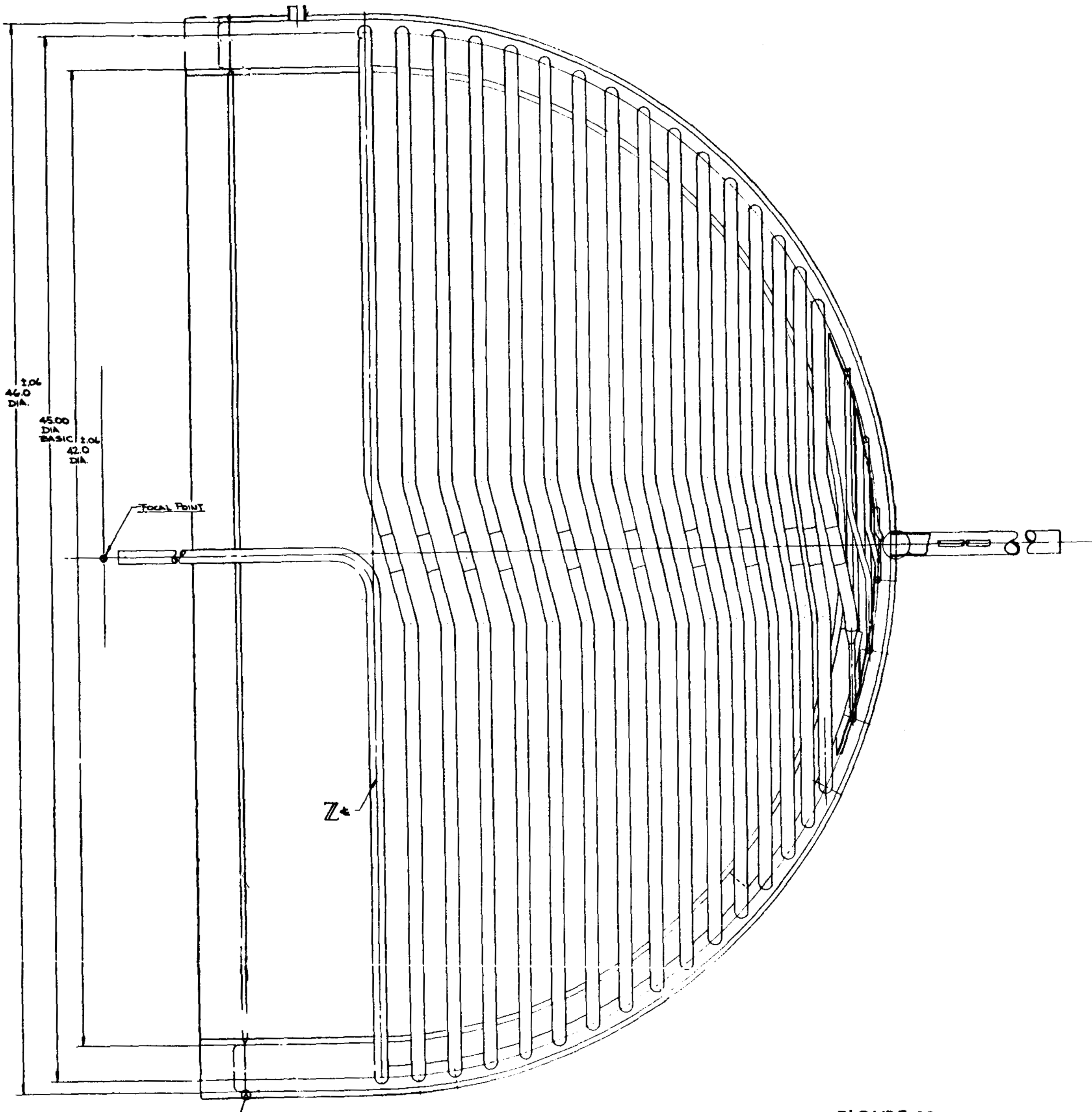


FIGURE 10

PREPROTOTYPE BOILER/HEAT STORAGE UNIT TOP VIEW

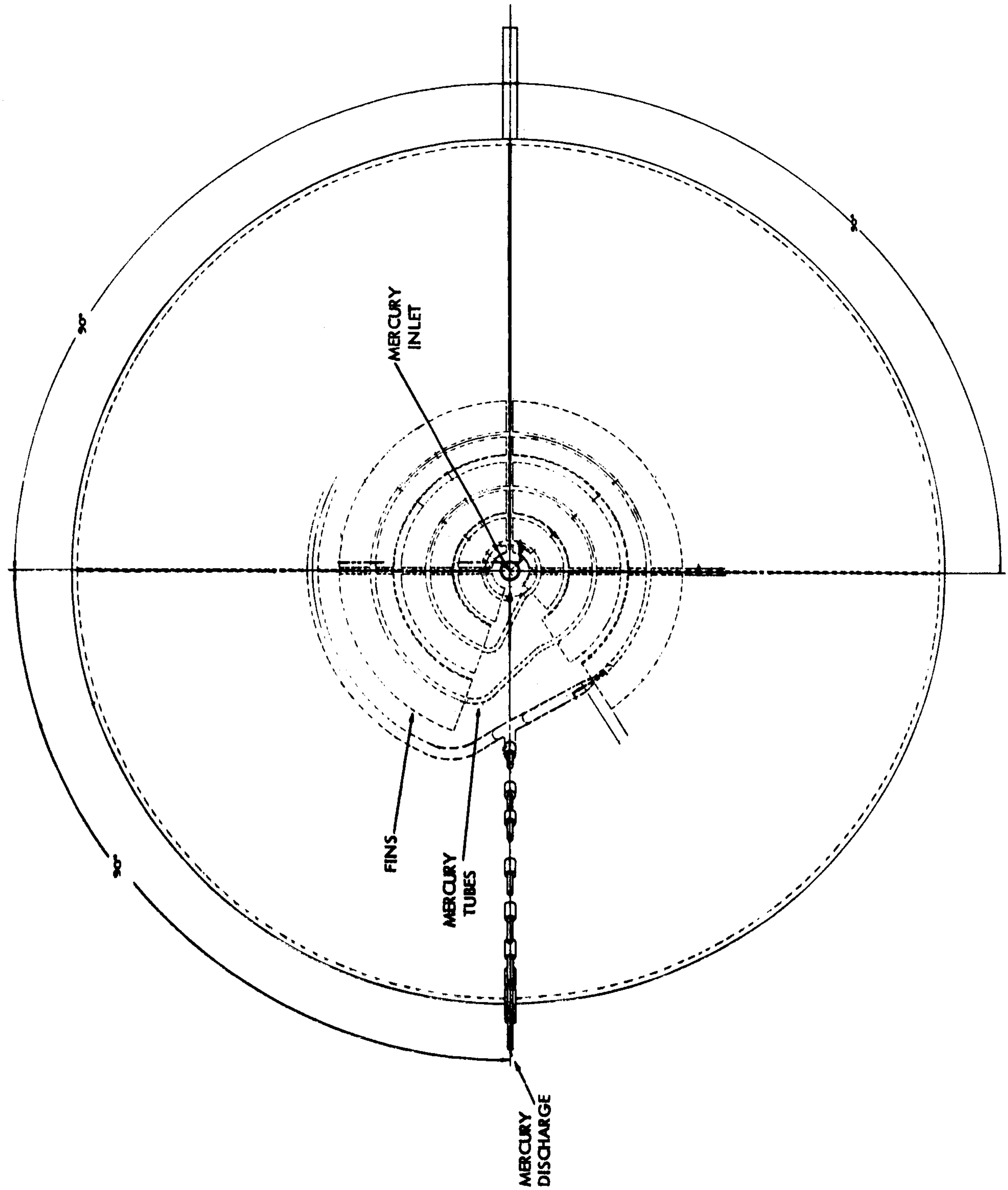
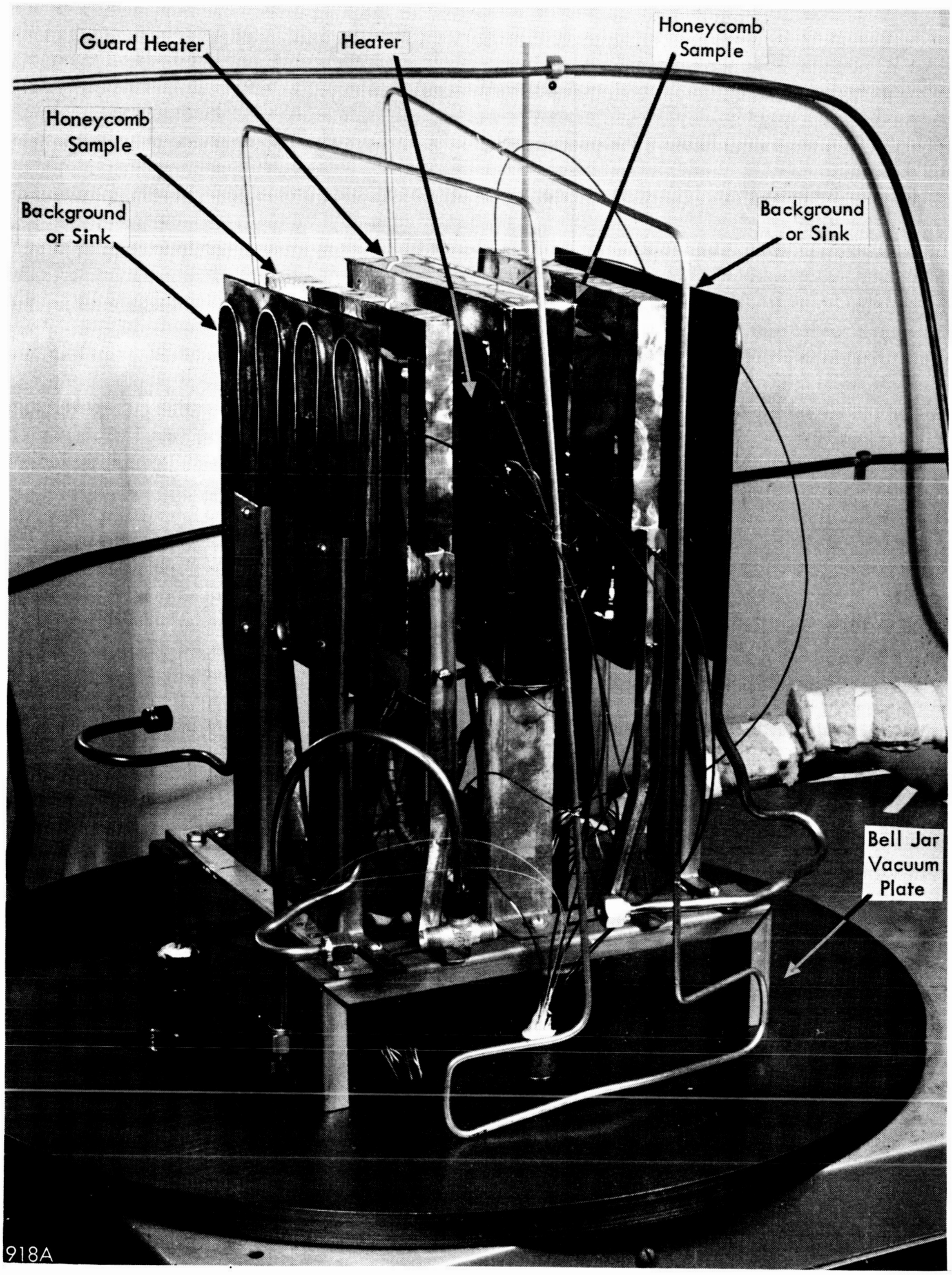


FIGURE 11



COLLECTOR ΔT TEST RIG

FIGURE 12

COLLECTOR TEMPERATURE (ΔT) TRANSIENT DURING SUN-SHADE OPERATION

LOW ALTITUDE ORBIT

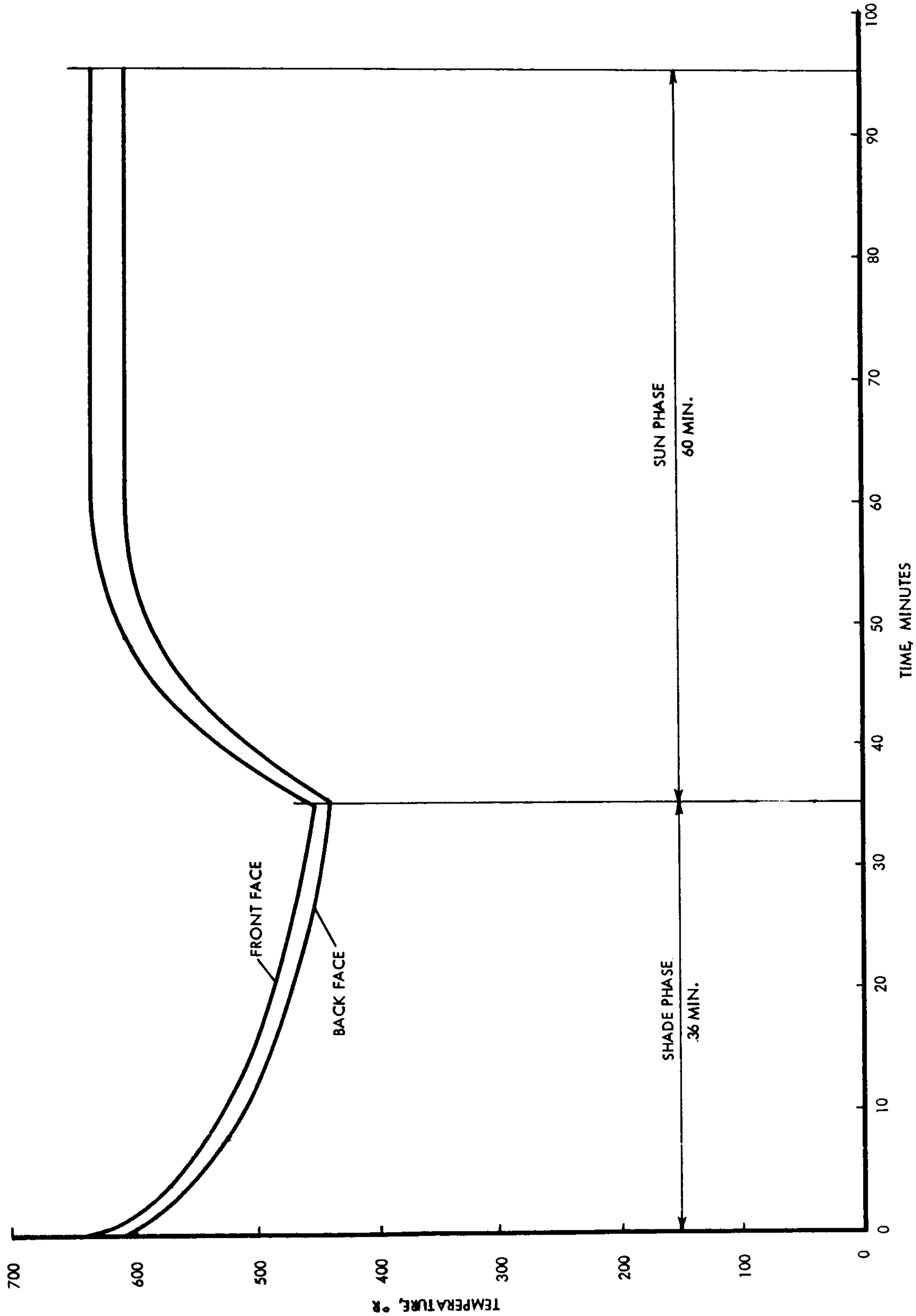


FIGURE 13

aimed at finding adhesives with relatively high conductivities.

Testing of the ten-foot model collector has been completed and included optical testing and deployment actuation. Flux distribution data from this 90° aperture collector has been analyzed and extrapolated to the Sunflower collector. Extrapolation shows that the predicted local surface quality requirements will be met. Deployment precision evaluation cannot be checked on the small collector.

Deployment test of the collector defined the opening kinematics of the petals. The initial torsion springs utilized did not have sufficient spring rate to overcome some inter-petal friction; thus insufficient petal inertia prevented complete closing of the locking device. Stiffer torsion bars were inserted in the hinges and the collector was again deployed. The operation was markedly improved; however, a design change in the petal locking device to reduce sensitivity in final petal kinetic energy will be investigated.

A small test rig has been fabricated which is to be used for calorimeter testing of four of the ten-foot collector panels. Preliminary testing has been completed which checked out the operation of the tracking mechanism and the counterbalancing of the collector petals. These tests have been satisfactory. As soon as the calorimeter is completed, tests will be performed to measure collector efficiency.

A recent evaluation of collector packaging in the nose cone has revealed that by modifications in the stacking ring and petal tip configuration the number of petals can be reduced to approximately 30. A rerun on the Burroughs 205 computer was made to check on petal stresses and the following conclusions were reached:

1. Maximum stress condition occurs at the time of nose cone separation and is 5750 psi. Aerodynamic load must still be verified; assumed values are 2 psi.

2. The upper restraining hoop should be released prior to the lower, if possible, to reduce stress levels, although this is not mandatory.

3. The petals should be supported at three points during handling to avoid excessive deflections ($\approx$ 2.5 inches) occurring when lifted by the end.

4. Reaction values computed can be used in design of hinges, locks, supports, etc.

Quotations have been reviewed on the five-foot vacuum tank for applying reflective films. Prices ranged from $33,000 to $61,000 and some variation existed in the equipment to be furnished. Therefore, vendors have been asked to requote on a revised specification giving substantially more detailed requirements. All quotes are due before December 15.

CONDENSER-SUBCOOLER

The single-tube glass breadboard condenser test rig (Figure 14) was completed and testing was initiated. Breakage of several fragile glass fittings interrupted tests but the rig has been modified and is now operating satisfactorily.

An initial test in which the mercury is condensing upward to simulate negative "g" forces has shown the feasibility of maintaining an interface in the required section of the rig. Pressure drop readings have varied between 0.35 and 0.95 psi for the full-length tube at various flow rates and indicate preliminary correlation with design condenser pressure drop.

Breadboard testing will be continued in both the vertical upward and downward positions until a complete performance map is obtained. The picture and test apparatus shows a modification to provide forced convection cooling to reduce condenser pressure level to design conditions. Higher flow regimes are needed to complete the overall condenser testing.

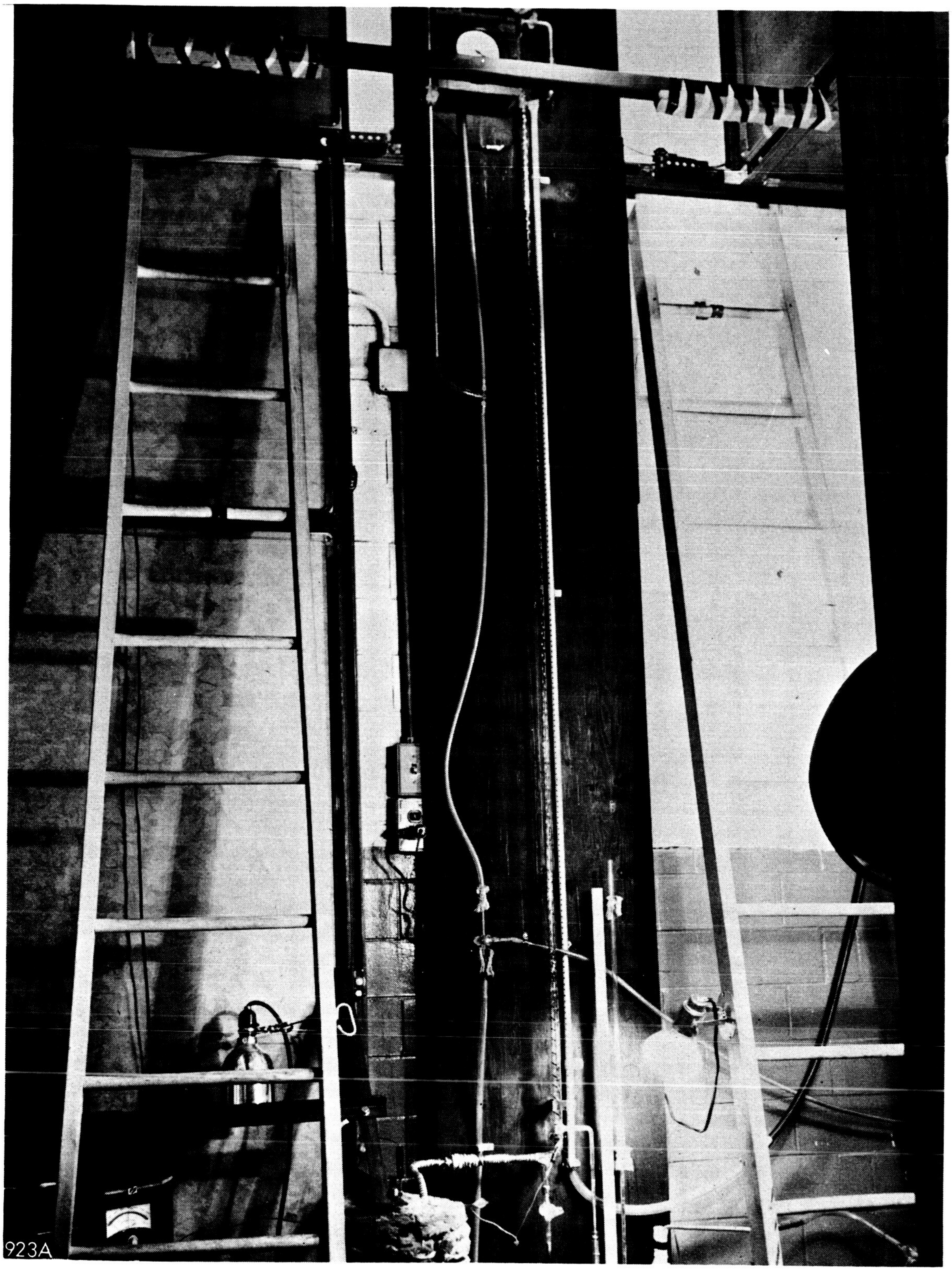
Preliminary pressure drop tests were conducted with a full-scale model of the subcooler heat exchangers. The pressure drops in the coiled tube were compared to pressure drops obtained in an equivalent length of straight tubing of identical dimensions, and, as expected, slight increases in ΔP were noted. Although the increase from coiling was small, it was noted that the ΔP in the straight tube was approximately twice the pressure drop which would be predicted by conventional pressure drop calculations. Additional tests will therefore be made as soon as the mercury facility becomes available.

The preprototype condenser design is completed with the exception of appropriate heater wires necessary for orbital and ground preheat. The radiator contains 18 tubes, 7.5 feet long, as shown in Figure 15.

The preprototype condenser design was also modified slightly to allow the condenser exhaust header to support the tube weight during the 10 g acceleration specification of launch. This maintains the condenser tube in tension and relieves the buckling stresses caused by supporting from the inlet header.

An investigation of feasible radiation surface coatings for space application was initiated. A chromium black coating as reported by Pratt & Whitney in "Research into High Emissivity Radiator Coating" appears to offer a possible solution to the maintenance of high emissivities.

Preprototype condenser and subcooler test plans and instrumentation requirements have been established. The objectives of the component tests are to simulate operating conditions at design, off design, and startup conditions. The test rig schematic is shown in Figure 16. Table I is a list of thermocouples and desired instrument accuracies.



CONDENSER BREADBOARD TEST RIG

FIGURE 14

CONDENSER PREPROTOTYPE DESIGN

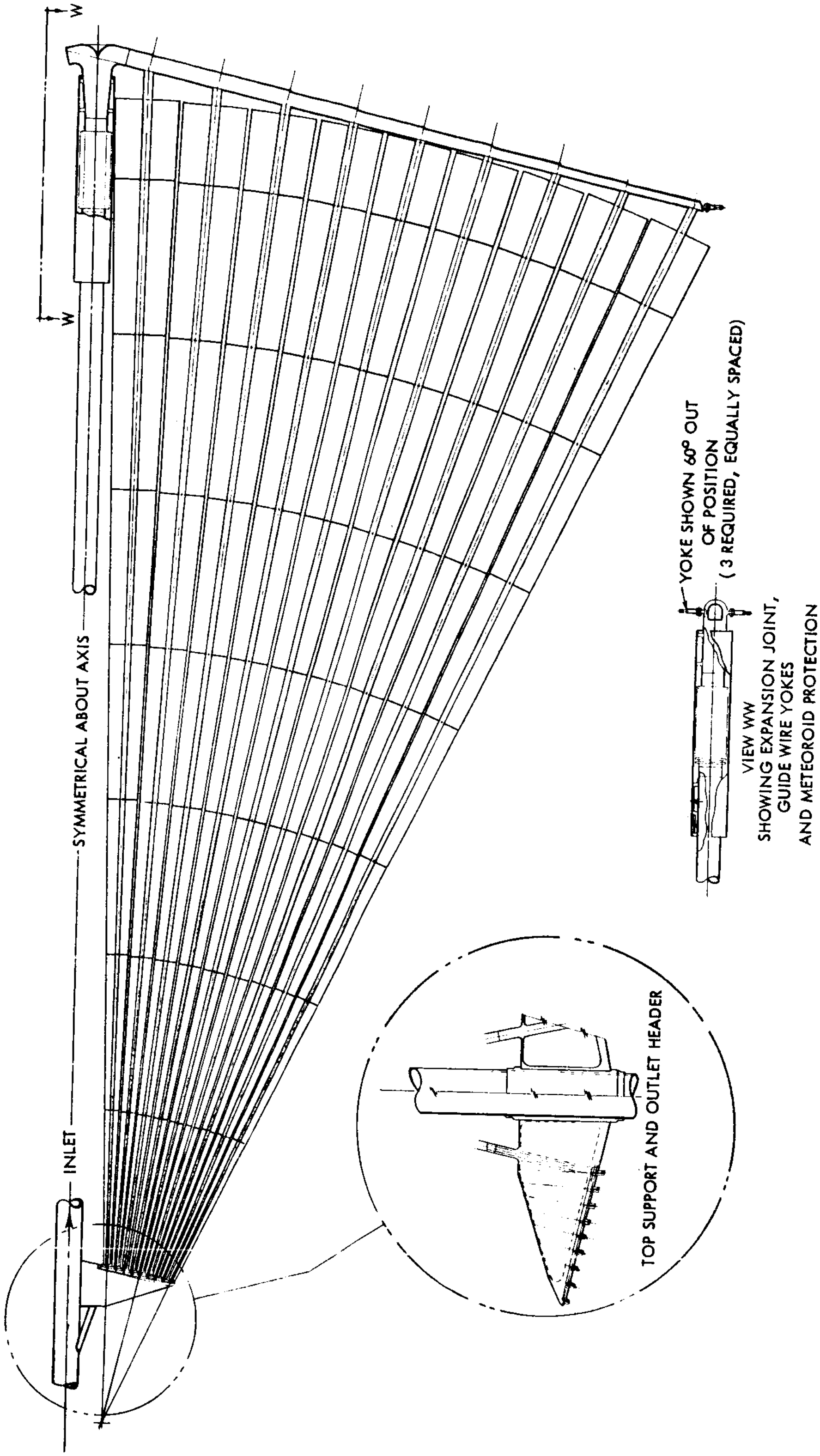
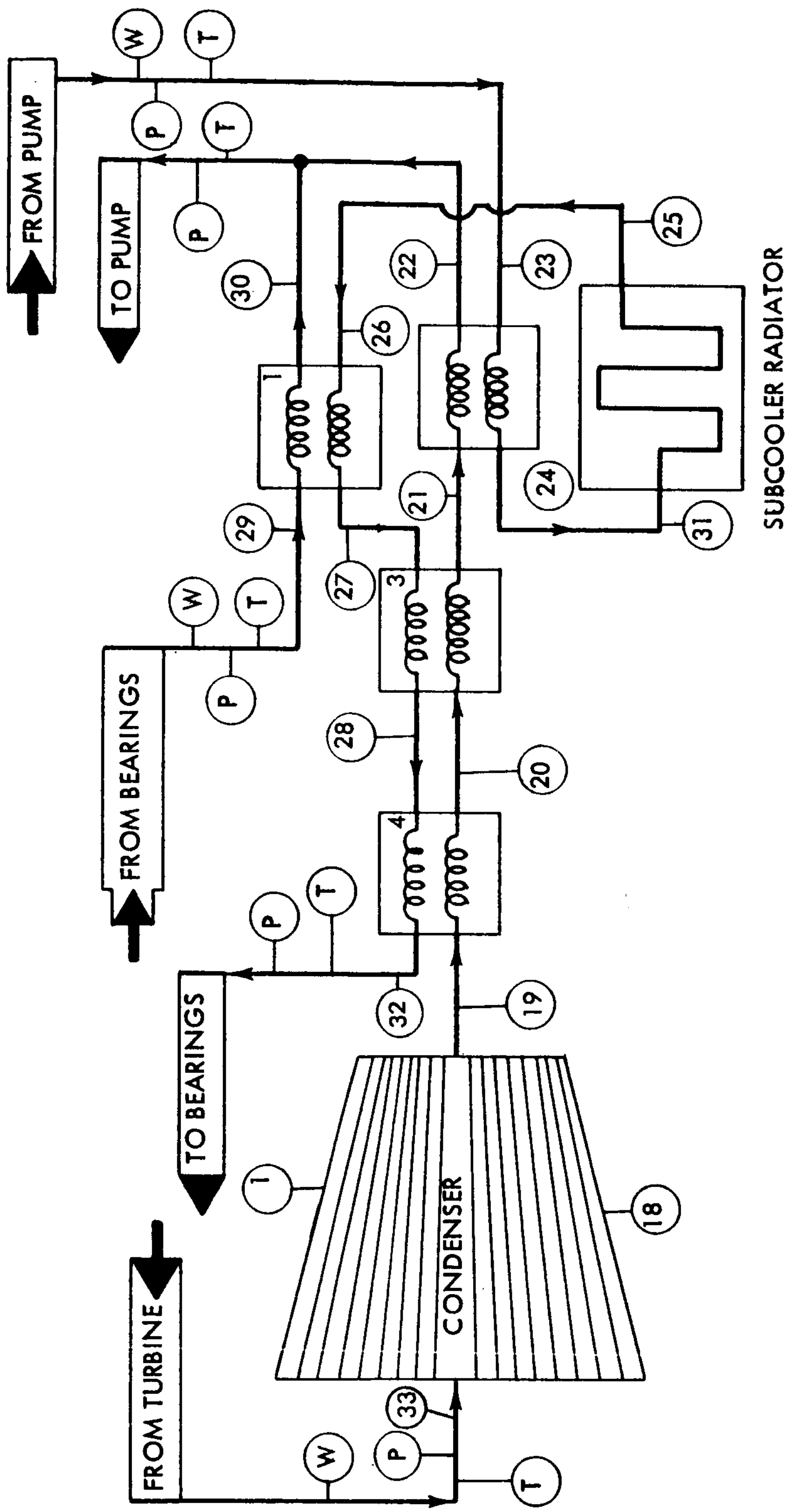


FIGURE 15

CONDENSER TEST RIG SCHEMATIC



W - WEIGHT FLOW

P - PRESSURE

T - TEMPERATURE

INLET AND OUTLET PARAMETERS
(Part of Test Booth Instrumentation)

FIGURE 16

TABLE I

THERMOCOUPLES AND DESIRABLE INSTRUMENTATION ACCURACY

No.	Location	Temp. Range
1 to 18	Along each condenser tube*	600 ± 50°F
19	Between condenser and heat exch. #4	580 ± 50°F
20	Between heat exchangers #4 and #3	580 ± 50°F
21	Between heat exchangers #3 and #2	520 ± 50°F
22	After heat exchanger #2, before bearing flow joins condenser flow	440 ± 50°F
23	Pump flow loop into heat exchanger #2	400 ± 50°F
24	Pump flow loop after heat exchanger #2	490 ± 50°F
25	Pump flow loop after subcooler radiator	330 ± 50°F
26	Pump flow loop before heat exchanger #1	330 ± 50°F
27	Pump flow loop after heat exchanger #1	450 ± 50°F
28	Pump flow loop after heat exchanger #3	510 ± 50°F
29	Bearing flow loop before heat exchanger #1	480 ± 50°F
30	Bearing flow loop after heat exchanger #1	370 ± 50°F
31	Pump flow loop before subcooler radiator	490 ± 50°F
32	Pump flow loop after heat exchanger #4	550 ± 50°F
33	Condenser inlet	600 ± 50°F

DESIRABLE INSTRUMENTATION ACCURACY

Flow	± 0.2 lb/min	(± 1%)
Pressure	± 0.1 psia	(± 1/2%)
Temperature	± 12°F	(± 2%)
Quality	± 2%	(± 2%)

*Instrumentation need not be of the continuous read-out type.

COMBINED SHAFT UNIT (CSU)

A critical review of the two CSU design concepts, namely, the integral type shaft and the SNAP II type built-up turbine shaft resulted in the selection of the latter. The integral shaft design appears to have several advantages; however, it is an undeveloped design and since there is no CSU development time scheduled, the SNAP II type design was chosen.

A layout of the CSU is shown as Figure 17. This design is presently being detailed and will be released for fabrication January 1, 1961.

Complete thermal analysis of the CSU has been initiated. Data will be used to determine all critical package components fits and stresses and to establish heat loss values.

ORBITAL START CHARGING TANK

The dual tank breadboard system described in the last quarterly report was released for fabrication and is near completion. The test rig for this component has been completed and the required instrumentation is being set up. Figure 18 is a schematic of the test setup.

This test rig will be utilized in determining an adequate method of nitrogen bleed from the system after inventory discharge, as well as inventory delivery performance. Elimination of the high pressure gas from the charging tank is desirable to prevent diffusion of N_2 into the system over a long time interval.

Preliminary envelope and component requirements have been submitted for integration into the system.

TURBINE DESIGN

The Sunflower turbine has been designed and is presently being integrated into the CSU. Integration revealed that some of the assumptions which produced a 55 percent efficient turbine were optimistic. These assumptions basically concerned high pressure and interstage leakage. The system specifications have therefore been altered to reflect a 51 to 53 percent efficient turbine as discussed in this report under Project Management and System Analysis.

In an effort to arrive at a seal configuration which will minimize leakage, loss tests are being conducted on the following configurations:

1. Smooth shaft in a smooth bore
2. Smooth shaft in a groove bore
3. Grooved shaft in a smooth bore
4. Staggered type seal.

COMBINED SHAFT UNIT LAYOUT

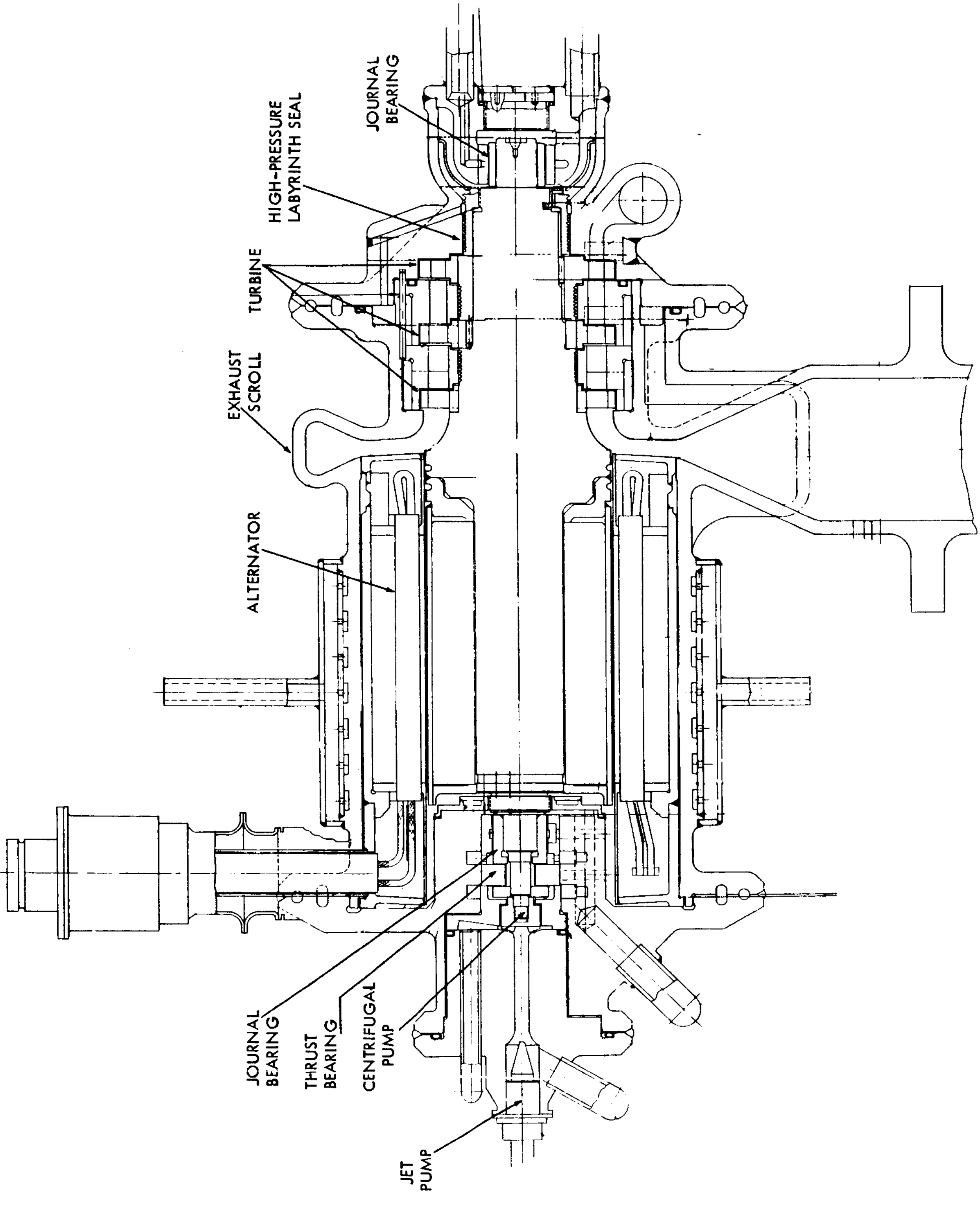


FIGURE 17

ORBITAL START CHARGING TANK TEST RIG SCHEMATIC

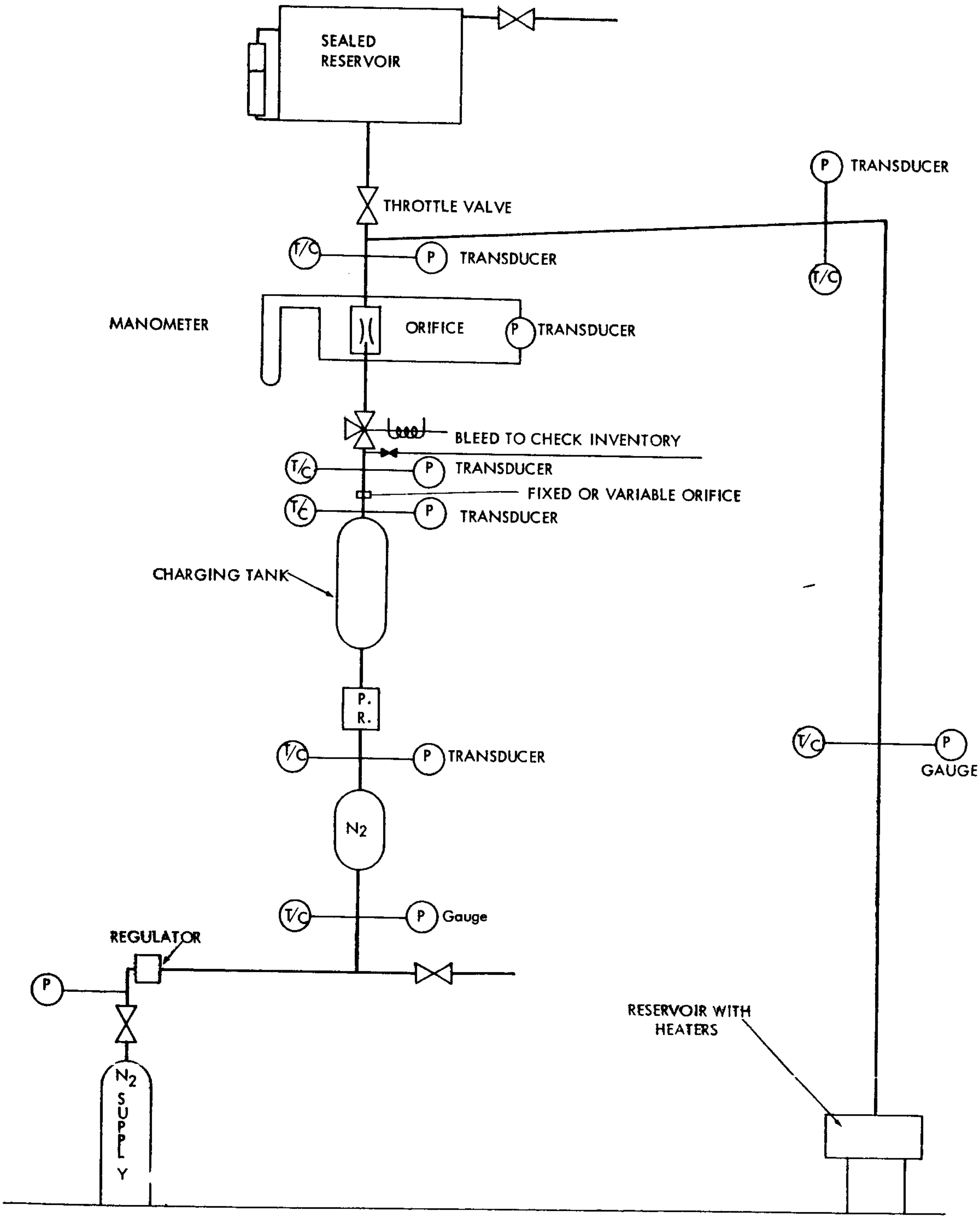


FIGURE 18

Figure 19 shows these configurations. The results of these tests will be factored into the CSU design during December.

ROTATIONAL SPEED CONTROL

Design of the initial breadboard unit has been completed and all purchase orders for the speed control parts issued. Mechanical construction of the control is 90 percent completed. The power diode cores are being wound and upon the completion of these items the breadboard control will be assembled and functionally tested.

LITHIUM HYDRIDE CORROSION

Construction and checkout of the test furnace were completed.

The initial tests included samples of Type 316, Type 347 stainless steels, Inconel X, Hastelloy C, and Haynes 25. The capsules were constructed from tubing specimens which were acid-cleaned prior to filling with the lithium hydride. To prevent oxygen and other contaminents from combining with the lithium hydride upon testing, the capsules were inserted in a dry box, hydrogen flushed, and kept under an argon cover gas while the ends were formed and spot and seam welded.

During the initial screening test, two specimen failure occurred. Lithium hydride leakage was observed from a Haynes 25 capsule after 32 hours of operation and a Type 316 stainless steel capsule after 290 hours. Examination of these capsules is not fully complete; however, radiographs of the failed capsules were made to determine the cause of failure. The radiograph of the Type 316 stainless steel capsule was inconclusive and that of the Haynes 25 indicated failure in the weld. Photomicrographs will be taken to determine the true cause of failure.

In summary, the various materials were tested for the following periods of time:

1 - Type 316 SS - 116 hours - initial screening sample

2 - Type 316 SS - 290 hours - failed (inconclusive to date)

3 - Type 316 SS - 529 hours

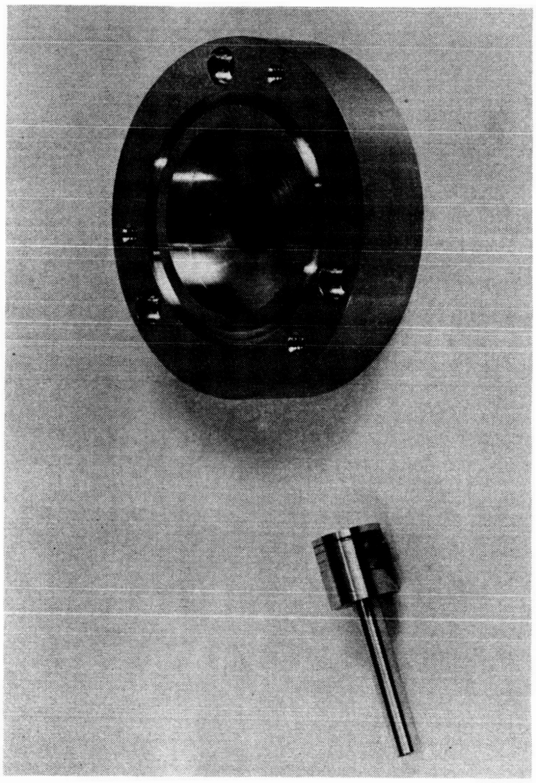
1 - Type 347 SS without lithium hydride - 290 hours

1 - Type 347 SS - 290 hours (severe arcing when capsule shorted Globar)

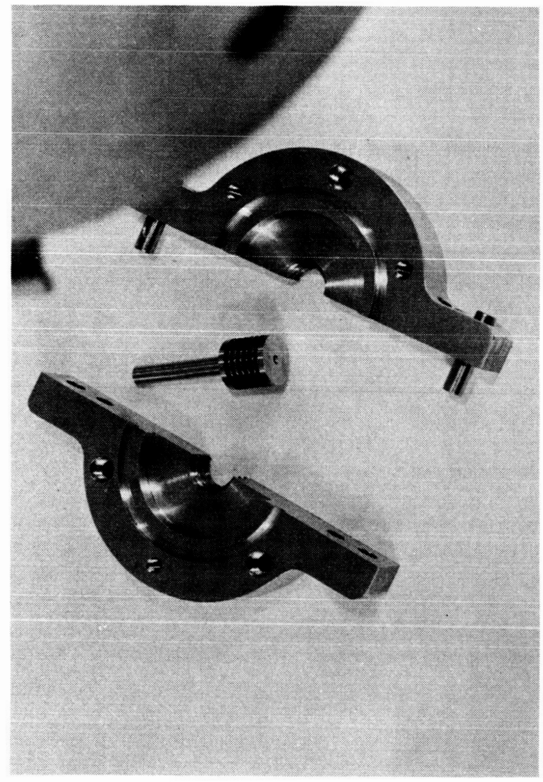
1 - Type 347 SS + Be - 290 hours

1 - Haynes 25 - 32 hours - failed (possible weld or crack failure)

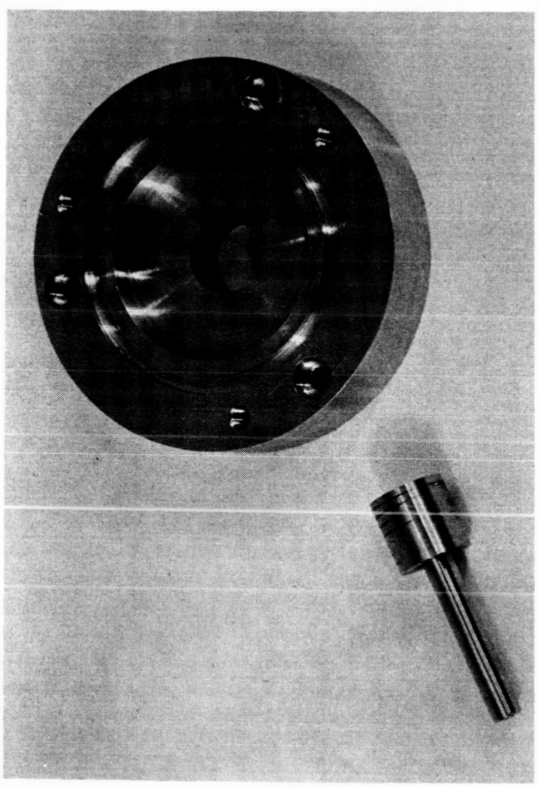
1 - Haynes 25 - 173 hours



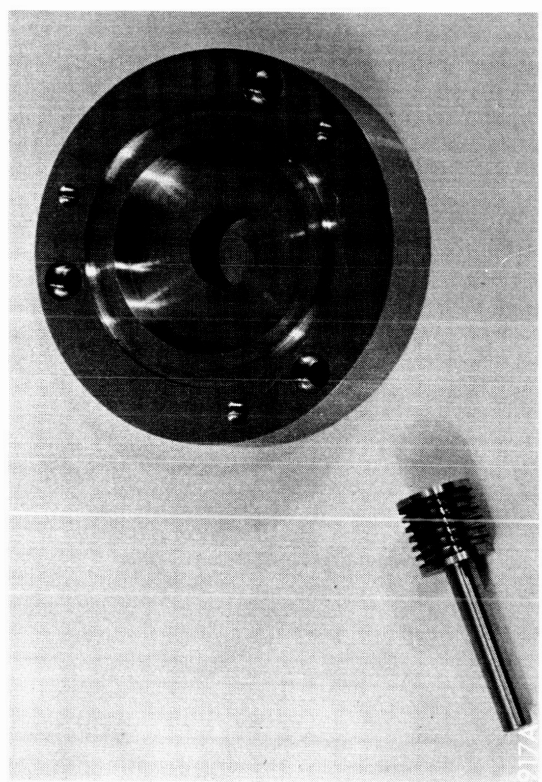
SMOOTH SHAFT IN GROOVED BORE



TURBINE LABYRINTH SEAL CONFIGURATIONS,
STAGGERED TYPE



SMOOTH SHAFT IN SMOOTH BORE



GROOVED SHAFT IN SMOOTH BORE

FIGURE 19

1 - Haynes 25 without lithium hydride - 173 hours

1 - Inconel X - 555 Hours

1 - Inconel X without lithium hydride - 555 Hours

1 - Hastelloy C - 555 hours

1 - Hastelloy C without lithium hydride - 555 hours

Examinations of these capsules are not fully complete; however, preliminary results of the Type 316 stainless steel screening capsules have indicated no apparent attack. Examination of a Type 347 stainless steel containing a beryllium slug indicated a 52 percent weight loss of the beryllium. No additional data are yet available, but preliminary indications concerning the use of beryllium as fin or structural materials in the boiler/heat storage component are not favorable.

The furnace is being converted to provide an argon atmosphere for the capsules. In attempting to run long-term, high-temperature controlled tests, the possibility of diffusing oxygen through the capsule walls and into the lithium hydride may present a condition which yields inconclusive or misrepresentative corrosion attack.

IV. CURRENT PROBLEM AREAS

The Sunflower program milestone objectives, such as completion of CSU fabrication and PCS delivery, are maintaining the original program objectives; however, the test program is behind schedule by approximately one month.

Delays have been encountered in completing pits and trenches for the shaker installation, delaying completion of the floor and erection of the test cells. Test activities have been rescheduled to maintain overall program objectives.

Considerable attention has been given to providing an inert argon cover in test cells when molten lithium hydride is present during testing. The most crucial problems exist in maintaining adequate seals at the cell doors and maintaining oxygen content sufficiently low to avoid the possibility of an explosive mixture of oxygen and hydrogen in the event of a hydride spill.

The lack of corrosion data for long-term exposures to molten lithium hydride is another critical problem, hindering choice of materials for the boiler heat storage unit. Corrosion testing is proceeding as rapidly as time and funds will permit; however, due to the tight Sunflower development schedules, material choices must be based on limited corrosion testing and conservative design.

In the boiler area the optimization conducted to determine minimum weight indicates that mercury tube diameters and Reynold's numbers should exceed those tested in the SNAP II system. Sunflower is presently planning to obtain the required correlations by running special tests at the relevent design conditions.

Another problem area which will require detailed development is the boiler startup transient-to-steady state operation. Several methods are being evaluated for controlling initiation of mercury flow and pressure to the boiler.

Thermal gradients across the honeycomb structure of the solar collector must be resolved so that preprototype drawings can be completed. A small vacuum tank capable of pressure levels down to 10^{-6} mm Hg is being purchased and will be set up immediately so that the ΔT problem can be further evaluated. This rig will also be used for studies of evaporative coatings and adhesive sublimation.

Quotations for the five-foot diameter reflective film vacuum tank are still outstanding. Further delays in purchasing of the tank will jeopardize the required schedule for application of the film to the preprototype collector panel and solar supplement backup support structure. Lead times noted on the quotations thus far received indicate time periods of 10 to 18 weeks. Even the earlier delivery date is cutting into the checkout and learning time available to the program.

Fabrication of long tapered tubes which are accurately controlled dimensionally and the brazing or joining methods for attaching the aluminum fins to the stainless steel mercury condenser tubes are considered problem areas. Two corporations, Le Fill Corporation and Kreisler Industrial Corporation, indicate they can fabricate the taper tubes. The brazing operation has been discussed with several manufacturers. A possible solution was outlined but will require several sample brazes. The suggested method is to build a brazing fixture with heating elements and thermocouples so that temperature can be controlled accurately throughout the fixture.

Recent design changes incorporated in the CSU package design have altered the axial location of the turbine exhaust scroll. The casting drawings are being expedited as rapidly as possible to allow the vendor the maximum time to produce suitable castings.

Vendor failure to meet the quoted delivery date has delayed testing of the orbital start component. As soon as delivery of the hardware is completed, breadboard testing of the components will begin.

A thermal map is being generated for the rotating package and will be evaluated to define heat restrictions and material and insulation requirements. The thermal map has been derived so that the matrix simultaneous equations can be solved on a computer. The complexity of the problem requires use of a computer with sufficient storage. Present plans are to rent a 709 computer in Washington, D.C. to run the equations.

V. PLANNED DIRECTION OF EFFORT FOR NEXT QUARTER

Continued system analysis will be directed toward modifying system component specifications as required by changes in component performance.

The Sunflower Solar Supplement is expected to be negotiated during December or early January. Slippage will compromise the availability of test results prior to the component final design freeze date of April, 1962.

Construction of the Development and Acceptance Test Rig enclosure will be completed and components will be installed in the Auxiliary Mercury Booth. Initial shakedown of the rig will be maintained as an objective; however, this is dependent upon completion of the floor and erection of the test cells.

Prototype development activity will concentrate on initiating design of the static loading fixture, condenser vibration test fixture, collector single-panel test rig, and CSU assembly test fixture. Co-ordination with Convair pertaining to ground checkout system requirements, launch site facilities, and general packaging requirements must be initiated.

The power conversion system layout drawing will be kept current with component development activities; any modifications required to maintain system integrity will be accomplished. Other activity will be directed toward studying manufacturing methods, particularly in the areas of condenser fin brazing and molybdenum boiler fabrication.

Boiler/heat storage effort will consist of finalization of prototype boiler configuration. Various modules will be breadboard tested to determine fin effectiveness. Breadboard boiler testing will be continued and test facilities will be designed.

Solar collector design layouts and details of the prototype collector design will be completed. Fabrication of the collector mold will be initiated. ΔT testing of honeycomb samples will continue and efforts will be made to evaluate effects of using adhesives with higher conductivity. Testing of the partial ten-foot collector with the calorimeter is to be completed and overall collection efficiency should be evaluated. The laboratory vacuum tank will be purchased and this facility installation will be nearing completion.

Condenser breadboard testing will be finished and results of the testing evaluated and factored into the preprototype and prototype condenser design. Fabrication of the initial full-scale preprototype condenser and subcooler and of jigs and fixtures required for construction of the condenser and subcooler will begin.

Thermal analysis data for the combined shaft unit will be integrated into the design of the rotating hardware. Detail drawings of the rotating hardware will be released for fabrication and hardware manufacture initiated.

Fabrication, installation and testing of the orbital start tank breadboard system will be completed. Test data is to be analyzed and the results integrated into the prototype design.

Labyrinth seal testing and package heat transfer analysis will be finished. Seal losses will be determined and the most desirable configuration will be incorporated into the rotating package design.

Lithium hydride corrosion activity will be concentrated on fabrication of two more sets of test capsules for evaluation and on analysis of the original and second capsule sets. Detailed reports will be published. The lithium hydride furnace will be completely modified to provide argon inerting of the test section.